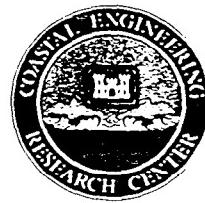




# Coastal Engineering Technical Note



## Coastal Structure Underwater Inspection Technologies

By Terri L. Prickett

### PURPOSE

To introduce multibeam sonar technology for use in performing high-resolution, quantitative surveys of coastal structures.

### BACKGROUND

Much of the damage to coastal structures, especially rubble-mound breakwaters and jetties, occurs to the underwater portion of the structure. Underwater damage such as scour, settlement, and scattering and breakage of armor units is not often exhibited on the surface, and damage can progress until a major structural collapse occurs. Detection of underwater damage and deterioration is cost-effective for coastal engineers in terms of planning for structure repairs and rehabilitation, and management of coastal structures over their lifetimes.

Using divers for underwater inspection or surveys of coastal structures is often difficult and risky because of the normal occurrence of waves and currents and limited underwater visibility around the structure. Information from diver surveys is subjective and spatial detail is sparse. Side-scan sonars (SSS) were investigated and proved as a viable tool for structural surveys (Kucharski and Clausner 1990). Although SSS surveys provide good spatial coverage, the results are semi-quantitative and often distorted because of energetic wave and current conditions around the structure.

In response to a need for objective, detailed, and quantitative definition of the underwater shape of coastal structures, research conducted at the U.S. Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center (CERC) under the Repair, Evaluation, Maintenance, and Rehabilitation Research Program (REMR-I) work unit "Evaluation of Damage to Underwater Portions of Coastal Structures" from Fiscal Year (FY) 1984 to 1989 focused on hardware identification, evaluation, and prototype design. This research resulted in development of the Coastal Structure Acoustic Raster Scanner (CSARS) system. REMR-II began in FY 1991, and development and testing of the CSARS system was continued under the work unit "Quantitative Imaging and Inspection of Underwater Portions of Coastal Structures," which focused on developing hardware and software tools to inspect underwater portions of irregular, rubble-mound coastal structures.

CSARS is a remote, bottom-deployed system consisting of a tripod containing a pointable 300-kHz acoustic transducer unit with driving motors and sensors. The CSARS tripod is cabled to an operator-controlled shipboard computer system allowing for real-time graphical display and onsite data post-processing. The device performed successfully in field trials at several coastal sites. A more detailed description of the CSARS system and its development is found in Lott, Howell, and Higley (1990) and Lott (1991).

In addition to CSARS development, newly emerging technology for monitoring coastal structures was investigated during REMR-II, resulting in the discovery of high-resolution multibeam sonar systems in the commercial market. State-of-the-art, high-resolution multibeam sonar systems have evolved from technological advances on several fronts, including the development of Differential Global Positioning Systems; advanced computer hardware and software capable of collecting, storing, and processing dense data sets; improved motion compensators; and roll, heave, and pitch sensors. The combination of advanced positioning and motion sensors with new sonar technology resulted in state-of-the-art, swath systems suited for shallow-water survey applications such as coastal structure condition assessment surveys. These commercially available systems proved superior to the still-prototype CSARS system, and CSARS development ended in 1993. Focus was directed toward investigation of multibeam sonar system applications for inspection and surveying of coastal structures. For this investigation, the SeaBat 9001 developed by RESON, Inc., of Goleta, CA, was selected for testing above other multibeam systems because it was more compact and less expensive.

## SEABAT 9001 SYSTEM DESCRIPTION

The SeaBat 9001 is a portable, downward and side-looking single-transducer multibeam sonar system. The main component of the SeaBat system is an acoustic sonar head operating at 455 kHz that transmits 60 sonar beams spaced at  $1.5^\circ$  in a fan pattern to provide a maximum sounding swath of  $90^\circ$ . This configuration enables swath coverage of twice the water depth. The sonar head is typically vertically deployed from a fixed mount off the side of the small vessel and is cabled to an external computer or data logger that controls display, data processing, and output in real time. A pointer device such as a trackball or joystick is used for operational control of the sonar head. The sonar head is tiltable for mapping steeply sloped or vertical structures to the water's edge. The SeaBat mounting and beam configurations are illustrated in Figure 1.

The SeaBat 9001 system can take 60 simultaneous soundings at a rate of over 15 profiles per second. SeaBat depth precision, in ideal conditions, is 0.13 ft below the sensor and 0.3 ft at the outermost beams at vessel speeds up to 12 knots (Headquarters, Department of the Army 1994). SeaBat images can be viewed in real-time and videotaped for data post-processing quality checks.

In addition to the SeaBat data, simultaneous measurements of vessel position, heading, and motion (heave, pitch, and roll) are required for post-processing geometric data corrections.

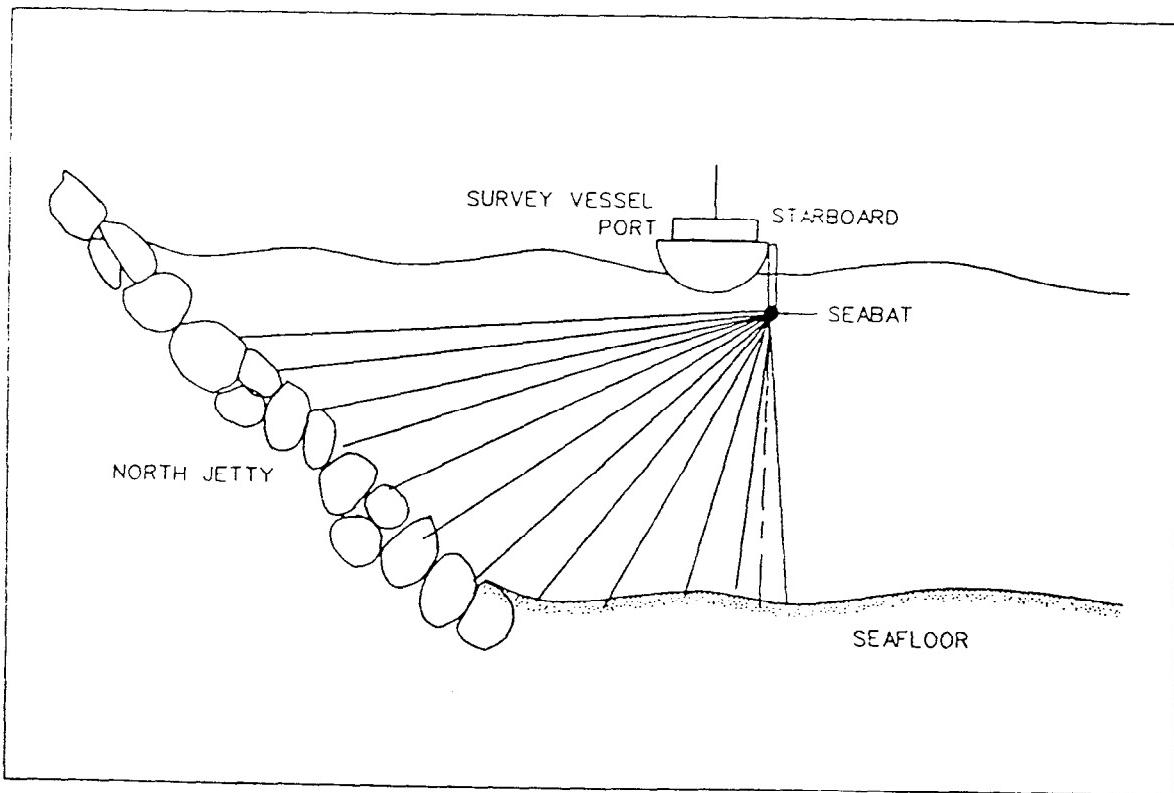


Figure 1. SeaBat mounting and beam configuration on steeply-sloping structure (Hughes et al. 1995)

Data corrections are necessary to produce accurate measurements of true depths referenced to vertical and horizontal datum for individual beams. Computer time tags of all data are also necessary. An overall system configuration is provided in Figure 2.

Once geometrically corrected and processed, the SeaBat provides a dense dataset of xyz coordinates of point data (spot elevations). From this dataset, a three-dimensional mesh surface connecting the spot elevations called a digital elevation model (DEM, also called a digital terrain model or DTM) can be created in addition to specified cross sections and contour maps. A DEM from the Yaquina Bay North Jetty Survey (see Table 1) is provided as an example in Figure 3.

## SEABAT FIELD DEMONSTRATIONS AND TRIALS

In 1993 and 1994, the Quantitative Imaging work unit was instrumental in disseminating information about the potential uses of the SeaBat system throughout the hydrographic survey community. As a result, several U.S. Army Corps of Engineers (USACE) Districts and hydrographic survey contractors sponsored SeaBat system demonstrations for varied applications. Table 1 lists those demonstrations attended by WES personnel. Demonstration attendees included personnel from other USACE Districts, academia, and private hydrographic surveyors.

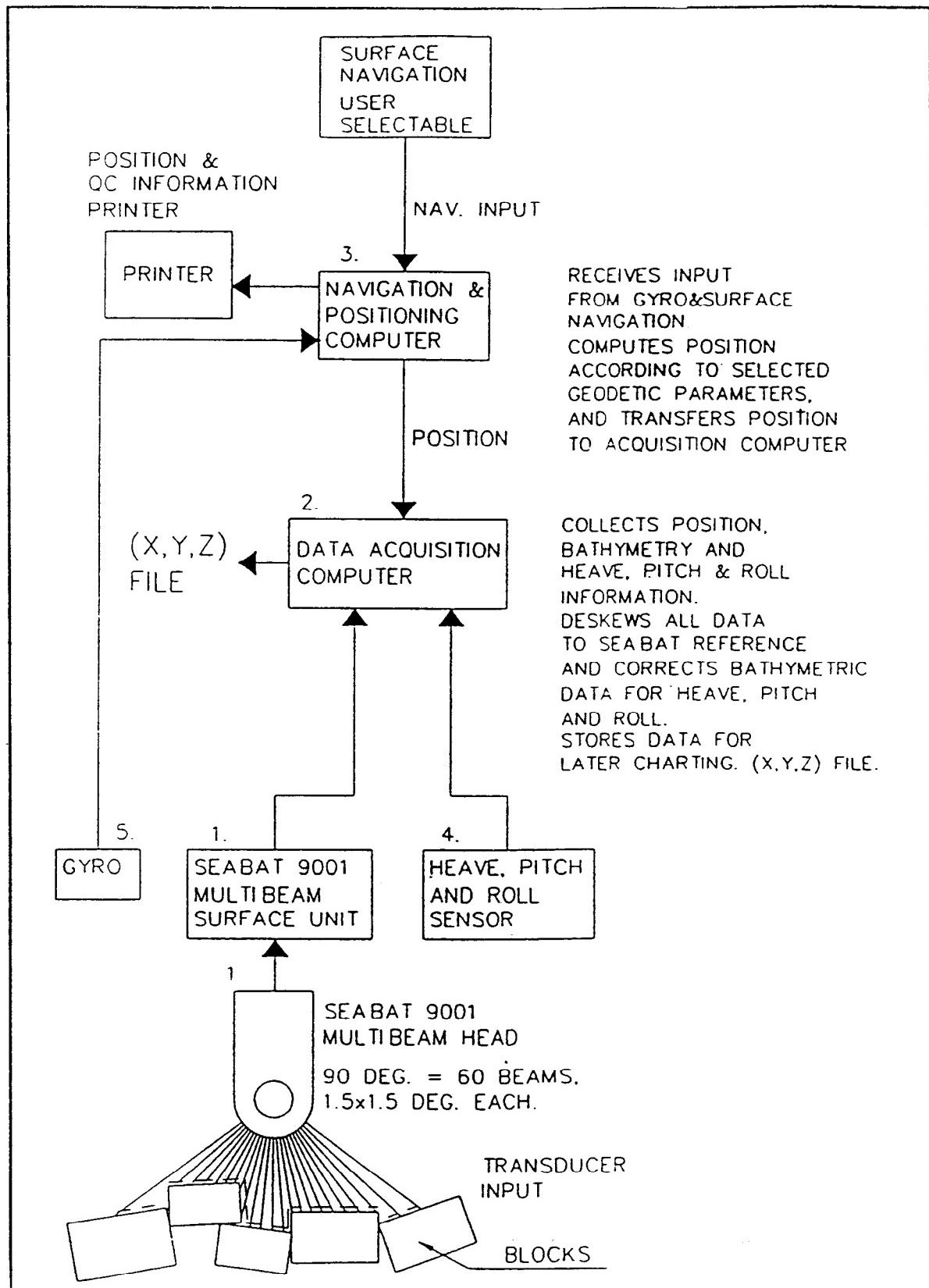


Figure 2. SeaBat overall system configuration (Headquarters (HQ), USACE 1994)

**Table 1**  
**SeaBat Demonstrations and Field Trials**

Sponsor	Location	Application
<b>Demonstrations</b>		
USACE District, Los Angeles	Los Angeles, California	San Pedro breakwater
USACE District, Memphis	Memphis, Tennessee	Bridge pier scour on the Mississippi River
Oceaneering, Solus Schall Division (Upper Marlboro, Maryland)	St. Louis, Missouri	Missouri River Bridge pier scour (after flood of 1993)
EMC, Inc. (Greenwood, Mississippi)	Crescent City, California	Harbor entrance survey (dolos inspection)
Ocean Surveys, Inc. (Old Saybrook, Connecticut)	Old Saybrook, Connecticut	Connecticut River entrance on Long Island Sound
WES	Duck, North Carolina	CERC Field Research Facility
<b>Field Trials</b>		
USACE District, Buffalo, and WES	Cleveland, Ohio	Cuyahoga River retaining structure reconnaissance survey
USACE District, Los Angeles, and WES	Los Angeles, California	Los Angeles (San Pedro) Harbor and Long Beach breakwaters
USACE District, New York	Long Island, New York	Shinnecock and Moriches Inlets
USACE District, Philadelphia	Rehoboth, Delaware	Indian River Inlet
WES and USACE District, Portland	Newport, Oregon	Yaquina Bay north jetty survey

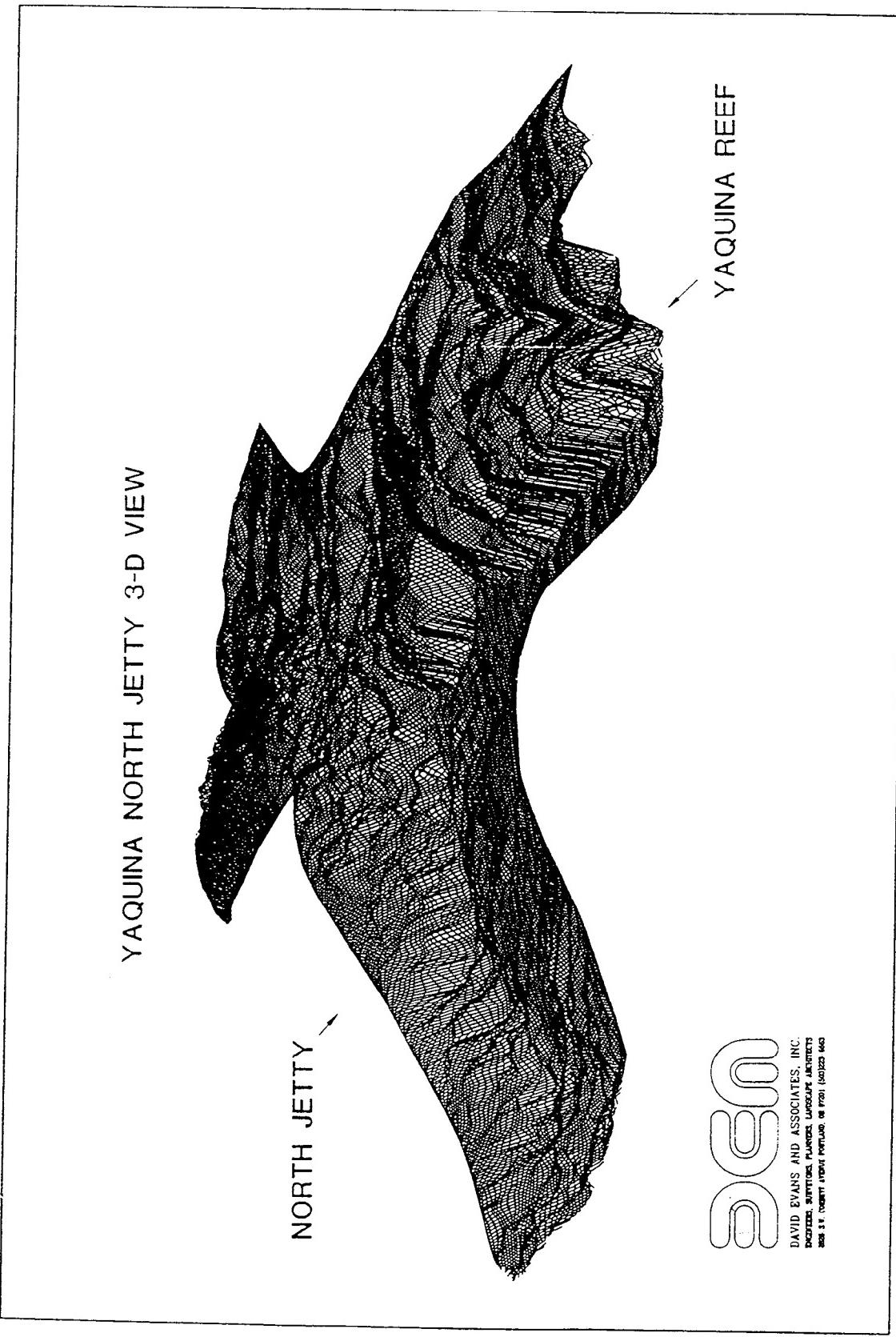


Figure 3. DEM of Yaquina Bay north jetty and Yaquina Reef below-water bathymetry

The Quantitative Imaging work unit also facilitated use of the SeaBat system during 1993 and 1994 for five successful field trials of Corps structural surveys (Table 1). For all of the field trials, the SeaBat system was able to provide valuable, previously unknown information on the underwater condition of the structures.

Development of the SeaBat system and its application to coastal structure surveys continued to evolve as the system was demonstrated and tested. Equipment improvements included innovative mounts and data collection hardware and software. Data collection procedures were tested, data density requirements were explored, and processing techniques were refined.

## SUMMARY

The demonstrations and success of the field trials have proved that the commercially available SeaBat multibeam system can be applied for use in coastal structure underwater surveys. Hydrographic surveying using state-of-the-art multibeam swath systems provides nearly 100 percent bathymetric coverage of the structure up to the water's edge, resulting in a detailed and quantitative definition of the underwater shape of coastal structures. The SeaBat swath systems and others like it are fast becoming standard equipment for shallow water surveying applications. Additional details of the SeaBat 9001 and description of other multibeam swath systems employed on USACE hydrographic survey contracts are provided in Engineer Manual 1110-2-1003 (HQUSACE 1994).

## ADDITIONAL INFORMATION

For further information contact Ms. Terri L. Prickett, Prototype Measurement and Analysis Branch, Coastal and Hydraulics Laboratory, at (601) 634-2337.

## ACKNOWLEDGEMENT

Recognition is given to Mr. Jonathan Lott, who participated in the REMR-I CSARS investigation and was the principal investigator of the REMR-II work unit until 1995. His superb research and technology transfer efforts resulted in escalating the development of multibeam sonars as a state-of-the-art tool for underwater surveying of Corps of Engineer coastal structures.

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